BMC Medicine

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Higher adherence to the EAT-Lancet reference diet is inversely associated with mortality in a UK population of cancer survivors

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Abstract

Background Significant advancements in treatment and care, as well as early detection, have contributed to an increase in cancer survival rates. Recently, the EAT-Lancet Commission on Food, Planet, Health proposed the "planetary health diet" but to date, no study has investigated the potential associations between adherence to the EAT-Lancet reference diet and mortality in cancer survivors. To determine whether higher adherence to the EAT-Lancet reference diet is associated with lower risk for all-cause, cancer, and cardiovascular mortality in cancer survivors.

Methods Data from the prospective UK Biobank study were used. Information from UK Biobank's Touchscreen questionnaire was used to develop a score reflecting adherence to the EAT-Lancet reference diet. Cox proportional hazards regression was used to assess the association of the EAT-Lancet reference diet score with all-cause, cancer, and cardiovascular mortality in cancer survivors.

Results Within 25,348 cancer survivors, better adherence to the EAT-Lancet reference diet was inversely related to all-cause mortality (hazard ratio (HR): 0.97, 95% confidence interval (CI): 0.95–0.99), 1 unit increase) and cancer mortality (HR: 0.98, 95% CI: 0.96–1.00), while mostly null associations were observed for major cardiovascular mortality (HR: 0.99, 95% CI: 0.95–1.03).

Conclusions Our findings suggest the adoption of the EAT-Lancet reference diet is associated with lower all-cause and cancer-specific mortality among cancer survivors.

Keywords Cancer, Survivors, EAT-Lancet, Diet, Mortality, Sustainable

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Background

Advances in early diagnosis and treatment options have contributed to the ongoing increase in cancer survival rates [1, 2]. According to the European Commission, it is estimated that over 12 million cancer survivors are living in Europe [3]. With the improvement in survival rates, there is an urgent need for evidence-based diet and lifestyle recommendations, tailored to the needs of cancer survivors. Although a wealth of knowledge exists on the link between potentially modifiable lifestyle factors and cancer risk, fewer studies have investigated how different lifestyle factors, including diet, might influence post-diagnosis outcomes [4–7] and more research on this topic is needed.

Research on the relationship between modifiable lifestyle factors and survival in cancer patients is limited and often reports conflicting results. Some studies have linked higher body weight, obesity, smoking, and alcohol consumption to increased mortality [8–10]. Conversely, engaging in physical activity and following high-quality dietary patterns, as well as consuming specific foods or food groups, have been associated with a reduced risk of death [5, 6, 8–11]. However, several studies did not confirm these associations, resulting in mixed findings [10]. Recently, the Global Cancer Update Programme published two comprehensive reviews on breast and colorectal cancer prognosis. These systematic reviews rated the data on dietary factors and outcomes after breast or colorectal cancer diagnosis as limited/ limited-suggestive for lower risk of the examined outcomes [12, 13]. Evidence on other cancers with respect to survival is even more sparse.

The EAT-Lancet Commission on Food, Planet, Health proposed in 2019 the "planetary health diet," also known as the EAT-Lancet reference diet. It is a mainly plant-based diet that, according to the EAT-Lancet Commission, addresses the environmental impact of food production and consumption better than most national food-based dietary guidelines [14]. The EAT-Lancet reference diet takes a similar stance on plant-based items as most national food-based dietary guidelines but is stricter in terms of animal-based product consumption, while plant protein sources are emphasized more strongly. Despite the widespread interest it generated, few studies have investigated whether the EAT-Lancet reference diet is also associated with lower risk of non-communicable diseases in the general population using cohort data. Most have reported a modest lower risk for all-cause mortality and non-communicable disease risk (e.g., cancer, cardiovascular disease, diabetes) with better adherence [15–23]. To the best of our knowledge, no published study has investigated the adherence to the EAT-Lancet reference diet in cancer survivors and its association with mortality.

In this study, we aimed to investigate the association between the EAT-Lancet reference diet and all-cause, cancer and cardiovascular mortality, overall and by predefined potential effect modifiers, in a sub-sample of the United Kingdom (UK) Biobank cohort comprising cancer survivors (i.e., with a previously recorded cancer diagnosis at the time of study recruitment).

Methods

Study population

The UK Biobank cohort is a large, population-based prospective study with over 500,000 participants throughout the UK. Detailed information on the study design, methods, and rationale of the cohort has been previously reported [24]. During the baseline assessment, information on medical, dietary, anthropometric, and lifestyle factors was collected, including information on alcohol use, smoking status, physical activity, education, reproductive history, and previous illnesses, including cancer. Study participants consented to be followed using linkages to NHS registers where health events and deaths were recorded.

A flowchart of the study population can be seen in Additional File 1: Fig. S1. Participants were included in the analyses if they had a recorded cancer diagnosis before their recruitment in the UK Biobank, based on linked data from cancer registries. Detailed information on the study population selection can be found in the Additional file 2: Additional Study Methodology. The mean time between cancer diagnosis and study recruitment was 8.56 ± 7.60 years.

Participants with a recorded death date between the date of recruitment and the latest date of complete information (30 September 2021 for England and Wales; 31 October 2021 for Scotland) were considered as all-cause mortality cases. When either the primary or secondary cause of death was recorded as C00–C97 or D00–D48 (10th Revision of the International Statistical Classification of Diseases, Injuries, and Causes of Death), these were considered cancer mortality cases; when they were recorded as I00–I25 or I27–I88 (10th Revision of the International Statistical Classification of Diseases, Injuries, and Causes of Death), they were considered cardiovascular mortality cases.

Adherence to the EAT-Lancet reference diet

Dietary information collected via the UK Biobank Touchscreen questionnaire was used to develop a score that reflects adherence to the EAT-Lancet reference diet. Information on dietary intake and the methodology

related to the development of the score can be found in the Additional file 2: Additional Study Methodology [25].

Study participants received a score based on whether each component of their diet was within the cut-offs of the EAT-Lancet reference diet (Additional file 2: Table S1). The dietary intake for females was rescaled to reflect a daily dietary intake of 2000 kcal, rounded to the nearest whole number (see Additional file 2: Table S1). The sum of all components resulted in each participant's overall EAT-Lancet reference diet score. Each component contributed equally to the overall EAT-Lancet reference diet score. Our scoring approach was largely based on the one described by Knuppel et al. [17]. When the UK Biobank Touchscreen information did not sufficiently capture the necessary information to operationalize the score like Knuppel et al., different scoring approaches were used (Additional file 2: Table S1). The score ranged from zero to eleven, with higher scores reflecting higher adherence to the EAT-Lancet reference diet. The score was additionally categorized into three groups, based on tertiles of the score in the study population.

Statistical analyses

Categorical variables were presented by percentages and continuous variables by arithmetic means and standard deviations (SD) for descriptive purposes.

Cox proportional hazards regression models were used to assess the association of the EAT-Lancet reference diet score with all-cause, cancer, and cardiovascular mortality in cancer survivors. The association with all-cause mortality was further explored in survivors of three frequently diagnosed cancer types (i.e., primary breast, primary prostate, and primary colorectal cancer). Entry time was defined as a participant's age at study recruitment and exit time as a participant's age at death, loss to follow-up, or end of follow-up, whichever came first.

The EAT-Lancet reference diet score was included in the models as continuous and as a categorical variable. We followed a tiered approach to adjust for potential confounders. Model 1 was stratified for age (5-year intervals), study assessment region (10 regions), and sex. Model 2 was further adjusted for education, Townsend deprivation index (quintiles; as an indicator for socioeconomic status), smoking status (never, former, current, prefer not to answer/missing), body mass index (BMI) categories ($\leq$18.5 kg/m^2,18.5–24.9 kg/m^2, 25.0–29.9 kg/m^2, $\geq$30 kg/m^2, missing; according to the World Health Organization classification [26]), physical activity (<75 min per week, 75–150 min per week, >150 min per week, prefer not to answer/missing), alcohol consumption (never, former, current drinker, prefer not to answer/missing), self-reported changes in the diet in the past 5 years, and time between the initial cancer diagnosis and study recruitment.

P values for trend were calculated using the median value of the tertiles in the models. We conducted preplanned stratified analyses by potential effect modifiers including sex, BMI, smoking status, alcohol intake status, self-reported recent dietary changes, and time between the initial cancer diagnosis and study recruitment. Sensitivity analyses were conducted, restricting the analyses to participants with at least two years of follow-up time. Analyses were conducted using Stata version 13 (StataCorp, TX). Associations with a two-sided $P<0.05$ were considered statistically significant.

Results

After an average follow-up of 11.5 years, 4781 deaths were recorded in the 25,348 cancer survivors of the UK Biobank cohort.

Almost 64% of the study participants were female with a mean age of 60 years at recruitment (Table 1). Almost 40% had a college or university degree, less than 10% were current smokers, and roughly one-third had a BMI of 18.5–24.9 kg/m^2. Participants with higher EAT-Lancet reference diet scores were more likely to be female; they were less likely to currently smoke or drink alcohol (Table 1). No marked differences were observed across the score categories in education, overweight/obesity, or physical activity.

The association between the EAT-Lancet reference diet, as expressed via a score, and all-cause mortality is shown in Table 2. Higher adherence to the EAT-Lancet reference diet was inversely associated with all-cause mortality (hazard ratio (HR)$_{continuous}$: 0.97, 95% confidence interval (CI): 0.95–0.99; HR$_{high\ vs.\ low:}$ 0.90, 95% CI: 0.84–0.99; *p*-trend: 0.004). When investigating the association in study population sub-groups diagnosed with selected primary cancer types (Table 3), higher adherence to the EAT-Lancet reference diet was inversely associated with all-cause mortality in participants diagnosed with breast cancer (HR$_{continuous}$: 0.95, 95% CI: 0.92–0.99; HR$_{high\ vs.\ low}$: 0.86, 95% CI: 0.76–0.98). A null association was seen in those diagnosed with colorectal cancer (HR$_{continuous}$: 0.98; 95% CI: 0.92–1.05; HR$_{high\ vs.\ low}$: 0.88; 95% CI: 0.68–1.13), while a positive association was seen for the continuous model in those diagnosed with prostate cancer (HR$_{continuous}$: 1.06, 95% CI: 1.01–1.12; HR$_{high\ vs.\ low}$: 1.18; 95% CI: 0.98–1.43).

The association between the EAT-Lancet reference diet, as expressed via a score, and cause-specific mortality is shown in Table 2. In analyses combining the primary and secondary causes of death, higher adherence to the EAT-Lancet reference diet was inversely associated with cancer mortality (HR$_{continuous}$: 0.98, 95% CI: 0.96–1.00; HR$_{high\ vs.\ low}$:

Table 1 Baseline characteristics of the study population, overall and by categories reflecting adherence to the EAT-Lancet reference diet

		EAT-Lancet reference diet score		
	Total (*n* = 25,348)	**Tertile 1 1–4 points (*n* = 12,263)**	**Tertile 2 5 points (*n* = 6078)**	**Tertile 3 6–11 points (*n* = 7007) [a]**
Age at recruitment, mean (SD)	60.06 (6.98)	60.09 (7.06)	60.01 (6.99)	60.06 (6.83)
Sex- female, %	63.61	60.78	63.52	68.66
Education, %				
O levels/GCSEs/CSEs or equivalent	24.34	24.51	24.79	23.63
A levels/AS levels/NVQ/HND/HNC or equivalent	14.82	14.89	14.86	14.66
College or University degree or Other professional qualifications	39.17	39.93	38.27	38.60
Prefer not to answer/missing	21.60	20.66	22.08	23.11
Smoking status, %				
Never smokers	51.23	50.59	51.10	52.46
Former smokers	39.47	39.42	39.59	39.47
Current smokers	8.85	9.62	8.80	7.54
Prefer not to answer/missing	0.45	0.37	0.51	0.53
Body mass index, %				
≤ 18.5 kg/m^2	0.64	0.68	0.72	0.50
18.5–24.9 kg/m^2	32.18	32.72	32.07	31.33
25.0–29.9 kg/m^2	41.67	40.85	41.41	43.31
≥ 30 kg/m^2	25.05	25.29	25.34	24.39
Missing	0.46	0.45	0.46	0.47
Alcohol intake status, %				
Never drinkers	4.40	4.11	4.08	5.19
Former drinkers	4.20	3.64	4.21	5.18
Current drinkers	91.31	92.19	91.63	89.48
Prefer not to answer/missing	0.09	0.07	0.08	0.14
Physical activity, %				
Less than 75 min per week	33.68	34.07	34.44	32.35
75–150 min per week	13.04	12.60	13.15	13.73
150 min or more per week	47.28	47.74	46.08	47.51
Prefer not to answer/missing	6.00	5.59	6.33	6.41

[a] The un-equal distribution in the tertiles is due to the people with the same score being grouped in the same tertile

Abbreviations: *A-level*, General Certificate of Education Advanced level, *AS-levels*, General Certificate of Education Advanced Supplementary level, *CSE*, Certificate of Secondary Education, *HNC*, Higher National Certificate, *HND*, Higher National Diploma, *GCSE*, General Certificate of Secondary Education, *NVQ*, National Vocational Qualification, *O-level*, General Certificate of Education Ordinary level, *SD*, standard deviation

0.92, 95% CI: 0.85–0.99; *p*-trend: 0.04). Null associations were seen in analyses on cardiovascular mortality in both the continuous and categorical models ($HR_{continuous}$: 0.99, 95% CI: 0.95–1.03; $HR_{high\ vs.\ low}$: 0.95, 95% CI: 0.82–1.09; *p*-trend: 0.36). Analyses restricted to the primary cause of death were largely similar (Additional File 2: Table S2), with slightly wider CIs due to the lower number of events.

The results of stratified analysis using predefined potential effect modifiers can be seen in Fig. 1 (all-cause mortality), Fig. 2 (cancer mortality), and Fig. 3 (cardiovascular mortality). Some differences were seen between the different groups for all-cause mortality, cancer mortality, or cardiovascular mortality. Depending on the outcome, females, people with a BMI of 18.5–24.9 kg/m^2 or ≥ 30 kg/m^2, current alcohol drinkers, and those diagnosed with cancer over 10 years before recruitment showed stronger inverse associations. Restricting the analyses to study participants with at least 2 years of follow-up time did not significantly modify our results (Figs. 1, 2, and 3).

Discussion

In this cohort of 25,348 cancer survivors, we observed modest inverse associations between the EAT-Lancet reference diet and the risk of all-cause mortality and

Table 2 The association between the EAT-Lancet reference diet and mortality in cancer survivors

	All-cause mortality			Cancer mortality*			Cardiovascular mortality*		
		HR (95% CI)			HR (95% CI)			HR (95% CI)	
	Events, *n*	Model 1 [a]	Model 2 [b]	Events, *n*	Model 1 [a]	Model 2 [b]	Events, *n*	Model 1[a]	Model 2 [b]
Continuous	4781	0.98 (0.96–1.00)	0.97 (0.95–0.99)	3780	0.98 (0.96–1.00)	0.98 (0.96–1.00)	1131	1.00 (0.97–1.04)	0.99 (0.95–1.03)
Tertile 1	2403	Ref	Ref	1876	Ref	Ref	572	Ref	Ref
Tertile 2	1150	0.97 (0.91–1.05)	0.96 (0.89–1.03)	921	1.00 (0.92–1.08)	0.99 (0.91–1.07)	256	0.92 (0.79–1.07)	0.90 (0.78–1.05)
Tertile 3	1228	0.92 (0.86–0.99)	0.90 (0.84–0.99)	983	0.94 (0.87–1.02)	0.92 (0.85–0.99)	303	1.00 (0.87–1.15)	0.95 (0.82–1.09)
p-trend		0.023	0.004		0.14	0.04		0.81	0.36

[*] Cancer and cardiovascular mortality were calculated on the basis of primary and secondary causes of death

[a] Model based on age, sex, and region

[b] Model based on age, sex, and region plus further adjustment for education, Townsend deprivation index, smoking status, body mass index, physical activity, alcohol consumption, self-reported changes in the diet in the past 5 years, and time between the initial cancer diagnosis and study recruitment

Abbreviations: *CI*, confidence interval, *HR*, hazard ratio. In analyses with breast and prostate cancer as outcomes, only participants with reported sex as female and male, respectively, were included

Table 3 The association between the EAT-Lancet reference diet and all-cause mortality in cancer survivors of selected primary cancer types

	Breast cancer (*n* = 8783)			Colorectal cancer (*n* = 2074)			Prostate cancer (*n* = 2959)		
		HR (95% CI)			HR (95% CI)			HR (95% CI)	
	Events, *n*	Model 1 [a]	Model 2 [b]	Events, *n*	Model 1 [a]	Model 2 [b]	Events, *n*	Model 1 [a]	Model 2 [b]
Continuous	1360	0.96 (0.93–0.99)	0.95 (0.92–0.99)	450	0.96 (0.90–1.03)	0.98 (0.92–1.05)	634	1.07 (1.01–1.12)	1.06 (1.01–1.12)
Tertile 1	655	Ref	Ref	236	Ref	Ref	291	Ref	Ref
Tertile 2	329	0.94 (0.82–1.07)	0.94 (0.82–1.07)	117	1.09 (0.87–1.37)	1.13 (0.90–1.43)	150	0.99 (0.81–1.21)	0.96 (0.78–1.17)
Tertile 3	377	0.87 (0.77–0.99)	0.86 (0.76–0.98)	97	0.83 (0.65–1.06)	0.88 (0.68–1.13)	193	1.21 (1.00–1.45)	1.18 (0.98–1.43)

[a] Model based on age, sex, and region

[b] Model based on age, sex, and region plus further adjustment for education, Townsend deprivation index, smoking status, body mass index, physical activity, alcohol consumption, self-reported changes in the diet in the past 5 years, and time between the initial cancer diagnosis and study recruitment

Abbreviations: *CI*, confidence interval, *HR*, hazard ratio. In analyses with breast and prostate cancer as outcomes, only participants with reported sex as female and male, respectively, were included

cancer-specific mortality. To the best of our knowledge, this is the first study to date exploring the adherence to the EAT-Lancet reference diet and its association with mortality in cancer survivors.

Low adherence to the EAT-Lancet reference diet was observed in our study population (score 0–4: 48.4%; score 5–7: 24.0%; score ≥ 8: 4.9%). Our findings are in line with previous publications that have found that cancer survivors do not follow healthy diets post diagnosis, with low adherence to most indices/guidelines investigated [10, 27–29]. Irrespective of the dietary indices, guidelines, or dietary recommendations examined in each study, cancer survivors generally adhered to the recommendation to abstain from smoking but otherwise scored poorly in terms of adhering to diet-related recommendations (e.g., 5-A-Day; World Cancer Research Fund/American Institute for Cancer Research; American Cancer Society) [10, 27–29]. The existing evidence highlights an area where further investment is needed to facilitate the adoption of healthier habits in the post-diagnosis period and investigate the barriers (e.g., treatment side-effects affecting appetite or taste) to healthy habit adoption in this population.

Despite the continuous increase in the number of people surviving their cancer diagnosis, thanks to early detection, screening programs, effective therapies, and care, few studies have investigated the association between post-diagnosis lifestyle and its relationship with mortality. To the best of our knowledge, few observational studies have investigated the association between the EAT-Lancet reference diet and mortality, including cancer-specific mortality [23, 30]. However, all these associations were estimated based on the dietary intake of a population free of cancer at the time of data collection, and as such are not directly comparable to our findings.

Limited evidence exists on whether the post-diagnosis lifestyle is associated with better post-diagnosis

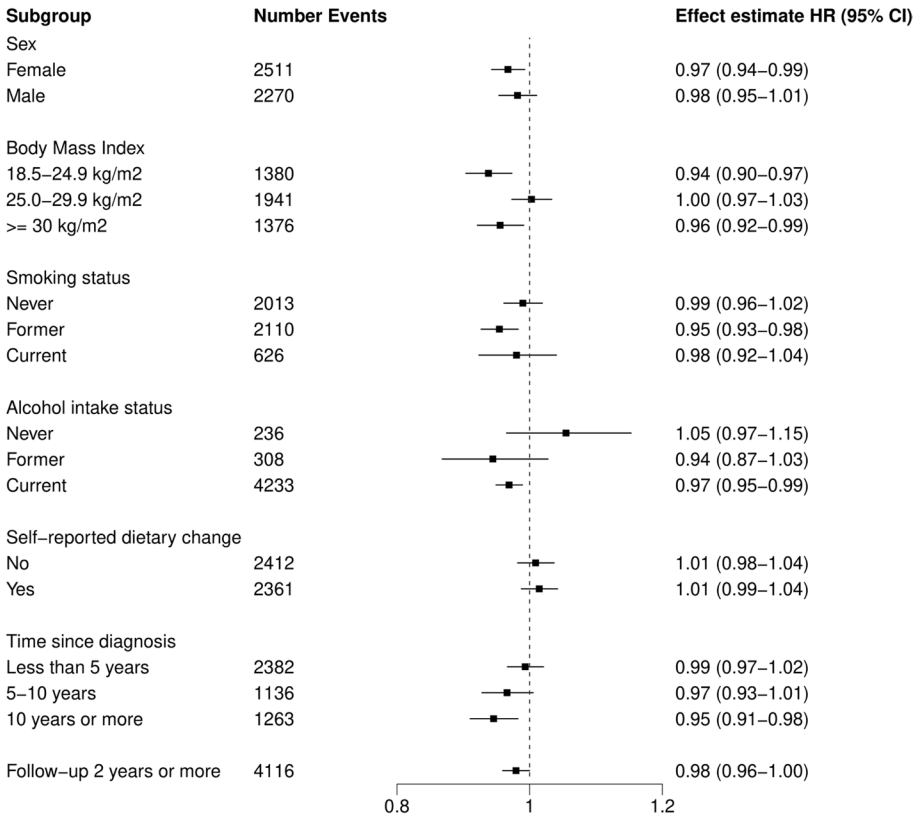

Fig. 1 The association between the EAT-Lancet reference diet and all-cause mortality, stratified by pre-defined potential effect modifiers

outcomes (e.g., recurrence, disease-free survival) in cancer survivors. The few studies in the available literature suggest that higher adherence to different dietary indices, dietary guidelines, or lifestyle patterns might be associated with a lower risk of all-cause mortality [4, 7, 10, 12] and improved survival [31]. The scarcity of evidence is particularly worrisome given that in the absence of evidence-based recommendations tailored to the needs of cancer survivors, most government bodies are simply recommending following the guidelines developed for the general population. As such, these recommendations and guidelines are unlikely to take into account the particular needs of cancer survivors (e.g., treatment side effects, need for long-term medication use). This lack of evidence-based recommendations tailored to the needs of cancer survivors has unfortunately been filled in many instances by practices not supported by the literature (e.g., excessive dietary supplement use) [32, 33].

In our study, we observed a null association between the EAT-Lancet reference diet and cardiovascular mortality. Studies in the literature have highlighted that, compared with people without cancer, adult cancer survivors have a significantly higher risk of cardiovascular disease [34]. We hypothesize that the lack of an association between the EAT-Lancet reference diet and cardiovascular mortality in our study might suggest that, given their higher risk and the monitoring they receive post-cancer diagnosis, cancer survivors are likely to receive medication (e.g., statins, antihypertensive drugs) and might not receive an additional benefit of diet on top of that.

The results of our stratified analyses highlighted some differences in the association between the adherence to the EAT-Lancet reference diet and mortality (all-cause or cause-specific). The sex-specific differences we observed could potentially be explained by the differential associations seen for the two main sex-specific cancers (i.e., breast and prostate cancer). Studies in prostate cancer survivors have reported heterogeneity of the effect of diet on survival based on survivors' Gleason score [35]. Unfortunately, information on survivors' Gleason score is not available in the UK Biobank and could not be used as an adjusting or stratifying variable in our study.

The findings supporting an inverse association with survival in survivors with BMI ≥ 30 kg/m^2 are in line with a recent study reporting no association of greater adiposity at diagnosis (measured by imaging) with worse

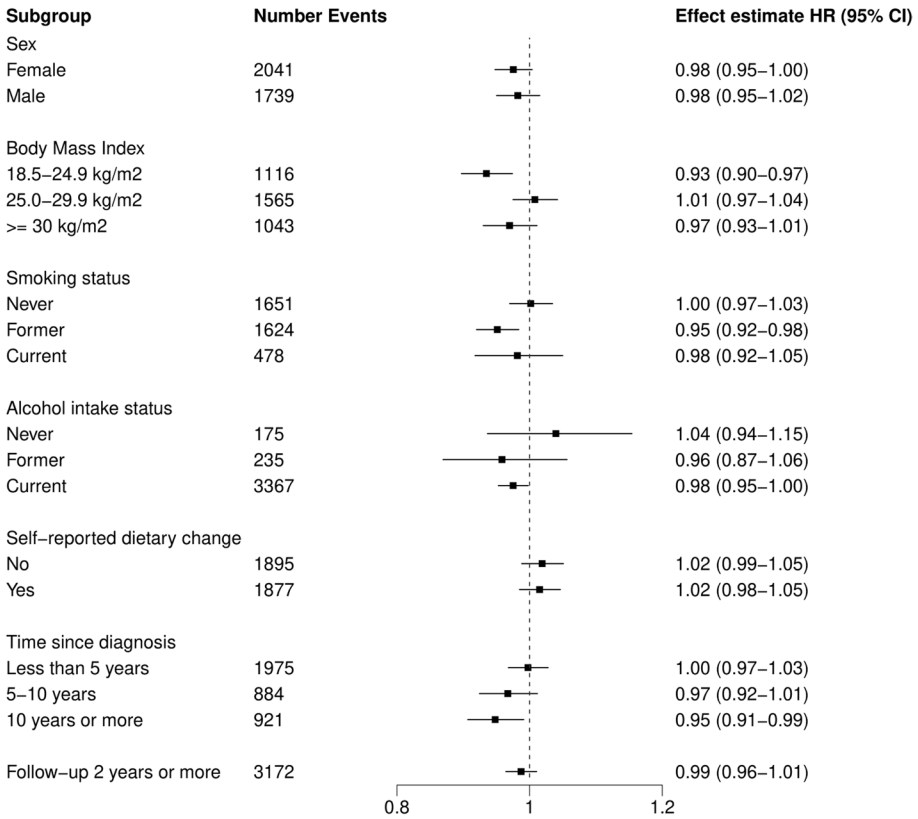

Fig. 2 The association between the EAT-Lancet reference diet and cancer mortality, stratified by pre-defined potential effect modifiers

survival among cancer survivors [36]. The reasons behind the observed survival benefits after cancer diagnosis are not entirely clear. This phenomenon could be explained by the association of obesity with less aggressive tumor subtypes with better survival outcomes, the reported higher tolerance of some anticancer therapies in patients with overweight/obesity, and the benefit of energy reserves in supporting the body during cancer treatment [33]. Larger studies will be necessary to look at different types of cancer. A recent study urged for the development and testing of intervention studies to increase our understanding of the health benefits of optimal body composition in cancer survivors [37].

The strengths of this study included the prospective study design and the substantial number of confirmed prevalent cases, but it also has some limitations. Dietary information was only available at baseline for the entire study population and may not reflect the long-term lifestyle habits of the study participants. To overcome this, we adjusted the study results by self-reported dietary changes. Another limitation is the lack of information on cancer stage and treatment and the potential effect these could have had on the dietary intake of the study population. To overcome this, we stratified our results based on the time between cancer diagnosis and inclusion in the study, assuming that the potential adverse effects of treatment are lessening over time. The dietary data collected with the Touchscreen questionnaire did not include all relevant information, so some components of the EAT-Lancet reference diet could not be operationalized in our study. Further, multivariable-adjusted models were unable to account for total energy intake calculated from the Touchscreen questionnaire due to the lack of dietary-related questions asked at recruitment. To account for potential reverse causation, we examined associations by follow-up time. However, results did not differ significantly when we excluded deaths that occurred during the first two years of follow-up. Cancer survivors that participated in the study are potentially healthier or have less aggressive disease compared with cancer survivors who did not participate in the UK Biobank cohort. As such, the present results might not be generalizable in people with more aggressive cancers.

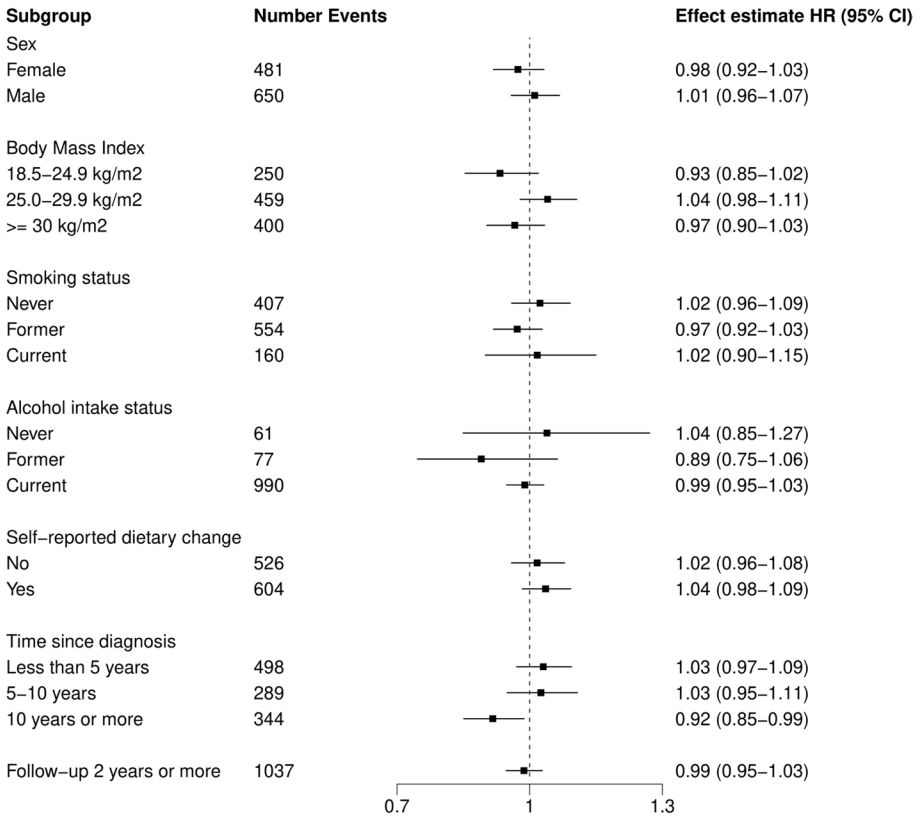

Fig. 3 The association between the EAT-Lancet reference diet and cardiovascular mortality, stratified by pre-defined potential effect modifiers

Conclusions

In conclusion, this large population-based study provides evidence to support that adherence to the diet proposed by the EAT-Lancet expert commission is associated with lower all-cause and cancer-specific mortality among cancer survivors. Additional studies are needed in this specific population to further assess their post-diagnosis needs as well as the perceived barriers to the adoption of healthy lifestyle habits.

Abbreviations

BMI Body mass index
CI Confidence interval
HR Hazard ratio
SD Standard deviation
UK United Kingdom

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-025-04106-x.

Additional file 1: This file contains Figure S1. Flowchart of study participants.

Additional file 2: This file contains Additional Study Methodology, Table S1. Operationalization of the components of the EAT-Lancet reference diet using the UK Biobank Touchscreen questionnaire and Table S2. The association between the EAT-Lancet reference diet and cancer- or cardiovascular-mortality in cancer survivors, based on the primary cause of death.

Acknowledgements

The authors would like to thank Dr. Anika Knüppel for her support in funding acquisition.

Authors' contributions

Conception and design: NK, AT, GP, KP, AC, TK, SR. Data acquisition: NK, SR. Analyzing the data: NK, TK, SR. Interpretation of the data: NK, AT, GP, TK, SR. Drafting the manuscript: NK. Critically revising the manuscript: NK, AT, GP, FS, KP, AC, TK, SR. All authors read and approved the final manuscript.

Funding

Funding for grant IIG_FULL_2021_012 was obtained from World Cancer Research Fund (WCRF UK), as part of the World Cancer Research Fund International grant programme. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability

This work has been conducted using the UK Biobank Resource (application number 81738). The UK Biobank is an open access resource and bona fide researchers can apply to use the UK Biobank dataset by registering and applying at http://ukbiobank.ac.uk/register-apply/.

Declarations

Ethics approval and consent to participate

The UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee. All participants provided informed consent.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 20 March 2024 Accepted: 28 April 2025
Published online: 13 May 2025

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